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TITLE

"METHOD FOR ASSEMBLY OF INSULATED HOUSINGS FOR ELECTRICAL EQUIPMENT AND INCORPORATION OF CIRCUIT INTERRUPTERS THEREIN"

FIELD OF THE INVENTION

This invention is concerned with improvements in housings for electrical equipment such as switching, measuring and control apparatus and methods for manufacture thereof.

Particularly, although not exclusively, the invention is concerned with a method for incorporation of a circuit interrupter into a pre-moulded insulating body.

The invention is also concerned with methods of application of a resilient insulating medium to a circuit interrupter prior to incorporation into an insulating body.

The invention is further concerned with a method of assembly of housings for electrical equipment.

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DESCRIPTION OF RELATED ART

PCT/AU94/04835 (WO 94/25973) describes an integrated high voltage system for switching power and sensing conditions within power lines. The system operates as a recloser or sectionaliser in power distribution networks.

The system comprises a vacuum interrupter initially pre-cast into an engineered, highly filled cycloaliphatic epoxy resin containing from about 68-73% of a ground silica filler. The epoxy encapsulated vacuum interrupter and other components are then encapsulated into a highly filled polyester based polymer concrete such as Polysil (Registered trade mark of The Electric Power Research Institute).

The coefficient of thermal expansion of the initial encapsulant is said to closely match that of the other components thereby avoid stress cracking at the engineered epoxy/Polysil interface.

US 5808258 describes an encapsulated high voltage switch comprising an elastomeric housing having a prefabricated tubular dielectric reinforcing element moulded or press fitted therewithin. A ceramic vacuum interrupter is disposed within the reinforcing element and surrounded by a dielectric filler material such as petroleum-based and silicone-based greases, silicone gels or RTV elastomers such as silicone rubber. The space between the vacuum interrupter and the tubular reinforcing element may be loosely packed with the filler material and mineral oil or silicone oil is introduced to swell the polymeric filler to provide a void free interface with the ceramic vacuum bottle.

US 5597992 describes a ceramic vacuum interrupter surrounded by a layer of polyurethane and encapsulated in a cycloaliphatic epoxy resin body.

PCT/US97/15936 (WO 98/11582) describes a method for casting a ceramic vacuum interrupter in an epoxy encapsulation.

This document deals with a method and apparatus for overcoming a stated prior art problem of direct epoxy encapsulation of polyurethane coated vacuum interrupters of the type described in US 5597992 above wherein differing coefficients of expansion of the polyurethane and epoxy materials lead to stress cracking in the epoxy encapsulant.

As the prior art demonstrates, there is an ongoing need to improve the method of incorporating ceramic vacuum interrupters in dielectric housing materials to reduce manufacturing costs and otherwise to improve the reliability of high voltage switching mechanisms in the field.

The prior art also demonstrates a pre-occupation with a ceramic vacuum interrupter which is permanently embodied in the epoxy housing by encapsulation at the time of manufacture of the housing.

While the prior art encapsulated vacuum interrupters may be generally effective for their intended purpose there are severe shortcoming and limitations associated with the final step of encapsulation of the vacuum interrupter in the interrupter housing.

PCT/US94/04835 and PCT/US97/15936 in particular deal with the

problems which can arise due to difference between the respective coefficients of thermal expansion of encapsulating materials and the ceramic vacuum interrupter housings.

PCT/US94/04835 seeks to overcome the thermal stress problems by utilising highly filled polymeric primary and secondary encapsulation materials having similar coefficients of thermal expansion.

PCT/US97/15936 utilises an expanded silicone rubber sleeve around the vacuum interrupter body to cushion the stresses in the epoxy encapsulation as it shrinks upon cooling. This specification claims that the expanded silicone has a coefficient of thermal expansion within the range of 60 to 90 x 10^{-6} mm/mm/°c and is relatively constant over the range of from -40°C to 160°C.

A possible disadvantage in the use of a preformed sleeve of elastomeric material is the difficulty in consistently obtaining a void free interface between the silicone rubber sleeve and the surface of the ceramic vacuum interrupter. Even when the sleeve is progressively shrunk on the ceramic surface from the middle towards the opposite ends, it is possible that there remains at least a mono-molecular layer of air or an air pocket which can provide a tracking path for partial discharging at the interface between the sleeve and the ceramic interrupter body.

It is stated in this specification that a liquid silane adhesion primer may be applied to the ceramic interrupter body or to the inner surface of the sleeve before the sleeve is applied to the interrupter body. Thereafter the bottle and sleeve are allowed to rest for 24 hours to enable the liquid silane primer to diffuse through the sleeve to enhance the bond between the sleeve and the epoxy encapsulation.

While a silane primer is required to enhance the ceramic/silicone bond, again it is considered that this technique can reduce that bond and actually draw air into the interface region as the liquid silane solution diffuses into the silicone rubber thereby creating a partial vacuum.

One of the greatest disadvantages of prior art epoxy encapsulated vacuum interrupters is that the electrical integrity of the encapsulating

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body cannot be tested until the assembly is complete. If the assembly is found to be deficient, due to air voids etc., the entire assembly, including an expensive, otherwise functional vacuum interrupter must be discarded.

Similarly another major disadvantage arises when the vacuum interrupter itself needs replacement. Because it is encapsulated in the epoxy body, it is not possible to simply replace the interrupter and again the entire assembly must be discarded.

While it would be advantageous to have modular high voltage switchgear housings which could be selectively assembled from pre-moulded epoxy or other polymeric compounds, there are difficulties in obtaining and maintaining joints between the elements with adequate electrical and mechanical integrity under varying service conditions.

OBJECTS AND SUMMARY

It is an aim of the present invention to provide an effective method for assembly of circuit interrupters.

It is a further aim to provide an improved method of assembly of housings for electrical equipment.

It is a further aim to provide, in a high voltage switching system, a replaceable vacuum interrupter.

According to one aspect of the invention there is provided a method of incorporating a vacuum interrupter into a housing, said method comprising the steps of:-

forming, on an exterior surface of a vacuum interrupter at least one polymeric sleeve of predetermined shape;

inserting said vacuum interrupter with attached said at least one sleeve into a locating cavity of pre-determined shape in a pre-moulded polymeric housing; and,

mechanically securing therewithin said vacuum interrupter with attached said at least one sleeve.

If required said at least one sleeve may be moulded directly on to an exterior surface of said vacuum interrupter.

Alternatively, said at least one sleeve may be preformed and subsequently attached to an exterior surface of said vacuum interrupter.

If required said at least one sleeve is moulded by a casting process with a flowable curable polymeric composition.

If required said at least one sleeve may be comprised of a substantially rigid material.

Preferably said at least one sleeve is comprised of an elastomeric material.

Suitably the polymeric composition has a dielectric strength in the range 10 to 30 kV/mm.

Said at least one sleeve may extend over at least part of the axial length of the exposed surface of said vacuum interrupter.

Alternatively said at least one sleeve may extend over one or more circumferential regions between opposed ends of the surface of said vacuum interrupter.

If required said at least one sleeve may comprise one or more circumferential rib-like projections.

Said one or more circumferential rib-like projections may comprise a helical screw thread adapted to engage a complementary screw threaded surface within said cavity.

The outermost surface or surfaces of said at least one sleeve are preferably adapted to be an interference fit in said locating cavity within said housing.

The cavity may comprise parallel inner side wall surfaces.

Preferably the cavity includes tapering inner side wall surfaces converging from a proximal end adjacent a mouth of said cavity to a distal end spaced therefrom.

The vacuum interrupter may be mechanically secured within said cavity by frictional engagement between said at least one sleeve and an inner wall surface of said cavity.

Alternatively the vacuum interrupter may be mechanically secured in said cavity by an adhesive material.

Preferably the vacuum interrupter is mechanically secured in said cavity by axial tension applied by a screw threaded fastener extending via an aperture in the base of said cavity to a screw threaded terminal of a fixed switch contact by said interrupter.

According to another aspect of the invention there is provided a method for removably locating an interrupter in an insulating housing, said method comprising the steps of:-

expanding at least one sleeve of flexible polymeric material;

positioning said at least one sleeve over a predetermined region of said interrupter;

allowing the sleeve to contract under tension about part or all of an outer wall of the interrupter;

inserting said interrupter with attached sleeve into a locating cavity of a predetermined shape in a pre-moulded rigid polymeric insulating housing; and,

removably mechanically securing in said cavity said interrupter with attached sleeve.

Suitably said at least one sleeve is allowed to contract about said interrupter under reduced atmospheric pressure.

If required said at least one sleeve may be expanded in a radial direction relative to a longitudinal axis of said sleeve.

Said at least one sleeve may be attached to an outer wall of said interrupter by an adhesive composition.

Suitably the outer surface of said at least one sleeve has a shape complementary to the locating cavity of said housing.

Preferably said at least one sleeve and the locating cavity have complementary tapered engaging surfaces.

The outermost surface or surfaces of said at least one sleeve are preferably adapted to be an interference fit in said locating cavity.

If required the cavity may have parallel inner wall surfaces.

Preferably the locating cavity tapers convergently from a proximal end adjacent a mouth of said cavity to a distal end spaced therefrom.

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If required said interrupter may have a plurality of axially spaced expanded sleeves.

Said at least one sleeve may comprise one or more circumferential rib-like projections.

If required the interrupter with attached sleeve may be removably secured in said cavity by axial tension applied by a screw threaded fastener extending via an aperture in the base of said cavity to a screw threaded terminal of a fixed switch contact of said interrupter.

Suitably said at least one sleeve is subjected to radial compression between said interrupter and an inner wall or walls of said cavity when secured therein.

Preferably said at least one sleeve is formed from a castable or mouldable polymeric material.

Most preferably said polymeric material is resilient.

The polymeric material is preferably elastomeric.

If required, the polymeric material may comprise a silicone polymer.

According to yet another aspect of the invention there is provided a method of assembly of an insulating housing for electrical equipment, said method comprising the steps of:-

securing over a spigot-like coupling member of an insulating housing element a layer of flexible polymeric material;

inserting, into a socket-like coupling member of an insulating housing element said spigot-like coupling member; and,

securing together said spigot-like coupling member and said socket-like coupling member under axial tension to induce radial compression of said layer of flexible polymeric material.

If required one or more cavities may be formed in an outer surface of said spigot-like member and/or an inner surface of said socket-like member to accommodate, in use, differential thermal expansion between said coupling members and said layer of flexible polymeric material.

Preferably said socket-like coupling member is heated before

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securing to said spigot-like coupling member whereby axial, thermal contraction of said socket-like member occurs upon cooling.

Said layer of flexible polymeric material may be formed from a castable or mouldable polymer.

Suitably said polymer comprises an elastomer.

Preferably said elastomer comprises a silicone polymer.

If required said socket-like coupling member and said spigot-like coupling member include coupling surfaces of complementary shape.

Suitably said socket-like coupling member and said spigot-like coupling member comprise complementary frusto-conical coupling surfaces.

The layer of flexible polymeric material may comprise at least one sleeve member.

Said at least one sleeve member may be radially expanded to accommodate said spigot-like coupling member.

Alternatively said at least one sleeve member may be cast or moulded about said spigot-like coupling member.

If required said at least one sleeve member may comprise a plurality of axially spaced sleeve members.

Said at least one sleeve member may comprise one or more circumferential projections.

If required said socket-like coupling member and said spigot like coupling member are subjected to axial tension to at least partially compress said layer of flexible polymeric material before said socket-like coupling member is allowed to undergo thermal contraction.

Mechanical and/or chemical adhesion may be effected between said layer of flexible polymeric material and respective contact surfaces of said spigot-like coupling member and/or said socket-like coupling member.

Suitably mechanical and/or chemical adhesion may be effected under a reduced atmospheric pressure.

According to a still further aspect of the invention there is provided

a method of coupling housing elements of an insulating housing for electrical equipment, said method comprising the steps of:-

forming complementary frusto-conical surfaces on respective socket and spigot coupling members of housing elements to be coupled;

establishing a temperature differential between a housing element having a socket coupling member and a housing element having a spigot coupling member whereby said socket coupling member undergoes thermal expansion relative to said spigot coupling member; and,

coupling said socket and spigot coupling members and allowing the temperature differential therebetween to dissipate whereby frictional engagement is achieved between respective housing elements with said spigot coupling element under radial compression and said socket coupling under circumferential tension.

Suitably said frusto-conical complementary surfaces are formed by machining.

If required said frusto-conical complementary surfaces are formed by grinding.

Preferably the complementary frusto-conical surfaces of respective socket and spigot members are lapped together using a lapping compound.

Suitably the taper angle of the complementary frusto conical surfaces is from 0.5° to an angle less than the angle of friction for the respective surfaces.

Suitably, the temperature differential between the socket and spigot coupling elements is in the range of from 20°C to 100°C.

Preferably the temperature differential is in the range of from 50°C to 80°C.

According to another aspect of the invention there is provided an electrical switching device embodying a circuit interrupter incorporated in an insulating body according to the abovedescribed method.

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BRIEF DESCRIPTION OF DRAWINGS

In order that the invention in its various aspects may be more readily understood and put into practical effect, reference will now be made to preferred embodiments described hereinafter and illustrated in the accompanying drawings in which:-

FIG 1 shows a cross sectional view of a sleeved vacuum interrupter located in an insulated housing.

FIG 2 and 3 show alternative embodiments of the assembly of FIG 1.

FIG 4 shows a cross sectional view of a high voltage recloser assembled in accordance with one or more aspects of the invention.

FIG 5 shows schematically the application under vacuum of an expanded sleeve to a vacuum interrupter.

FIG 6 shows a heat shrunk coupling between insulated housing element.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

In FIG 1, a ceramic vacuum interrupter 1 of a conventional type has a silicone rubber sleeve 2 having a generally cylindrical inner wall 3 and a frusto-conical outer wall 4.

The interrupter/sleeve assembly 1, 2 is located in a cavity 5 in a pre-moulded insulating housing 6, the cavity having a frusto conical inner wall surface 7.

The vacuum interrupter 1 is located radially within cavity 5 by means of compressive engagement between wall surfaces 4 and 7 and axially by means of a threaded stud 8 locating in the threaded socket 9 of a fixed switch contact of the interrupter via copper heat sink/conductor member 10. Vacuum interrupter 1 is axially tensioned by a tubular nut 11 engaging stud 8 whereby sleeve 2 is subjected to a degree of radial compression.

In the manufacture of sleeve 2, the outer ceramic wall surface of vacuum interrupter 1 is coated with a silane primer such a Wacker G 790

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which is recommended for addition - crosslinking silicone polymers.

After allowing the primer to dry at ambient temperature for about one hour or for about 15 minutes at 100°C, the vacuum insulator is located in a mould (not shown) to which is added a liquid room temperature vulcanizing (RTV) silicone rubber such as Wacker Powersil 600 - a two component addition curing compound.

The monomer and catalyst are mixed in the required ratio and the mixture is submitted to a reduced pressure of less than 20 mbar to remove any entrained air bubbles.

After deaeration, the liquid mixture is poured into the mould cavity and allowed to cure before removal from the mould.

The assembly, when removed from the mould has a void free interface between the sleeve and the ceramic surface of the interrupter. The high degree of adhesion thus achieved provides a degradation resistant electrical and mechanical integrity for the life of the interrupter.

The outer surface 4 of sleeve 2 and/or the inner surface 7 of cavity 5 of body 6 are then lubricated with a silicone oil or grease and the interrupter/sleeve assembly 1, 2 is pushed gently into cavity 5 with the fixed switch contact uppermost.

A threaded stud 8 is then inserted via aperture 12 in body 6 to engage the threaded socket 9 of the fixed switch contact.

A nut 11 is screwed on to stud 8 and gently tightened until it locates in its final resting place as shown.

The silicone rubber typically has a hardness of around 25 Shore A and when the vacuum interrupter is seated in its final resting place, sleeve 2 has undergone a compression of about 6-12%, preferably 7.5-8.0% in radial thickness.

Depending upon the degree of taper in the cavity 5 and/or the configuration of sleeve 2, silicone rubbers having a hardness of from 15 Shore A to 65 Shore A may be employed.

As an alternative to casting the sleeve 2 directly on to the surface of vacuum interrupter 1, the sleeve may be preformed from any suitable

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polymer by any suitable moulding means such as mould casting or injection moulding.

Because the dielectric constants of the sleeve 2 and housing 6 are so much greater than that of air, it is desirable to ensure that air is excluded from the respective interfaces between the outer surface 4 of sleeve 2 and inner wall 7 and in particular between the inner surface 3 of sleeve 2 and the vacuum interrupter 1 where even small air pockets can cause a partial discharge leading to premature electrical failure of the insulating sleeve.

Although for the purpose of excluding air, it is preferred to cast the sleeve 2 directly on to the vacuum interrupter under vacuum, there are other alternatives.

As described in International Publication WO 98/11582 (PCT/US97/15936) a cylindrical rubber sleeve is expanded by an inflatable bladder in a vacuum manifold to about 2-2½ times its original diameter. A silane primed vacuum interrupter is then inserted into the expanded sleeve before the vacuum suction is discontinued in the manifold whereby the sleeve collapses onto the interrupter under tension.

Due to the possibility of entrapment of at least a monomolecular layer of air or air pocket between the sleeve and the vacuum interrupter, it is preferred that the vacuum manifold be located in an evacuable chamber so that the sleeve can be collapsed onto the vacuum interrupter in almost the complete absence of gas molecules.

It is also preferred that the silane primer on the surface of the vacuum interrupter is at least partially cured before collapsing the silicone rubber sleeve thereonto.

By employing this method of manufacture, it is possible to test the electrical integrity of housing 6 before final assembly and thereby avoid the prospect of discarding an entire assembly with a relatively expensive vacuum interrupter in the event that the housing is found to be faulty after moulding.

Moreover, in the event of a vacuum interrupter failure, it can be

readily replaced without the expense of a complete assembly as with the prior art.

It will be readily apparent to a skilled addressee that many modifications and variations may be made to the invention without departing from the spirit and scope thereof.

For example, the preformed insulating housing body 6 is conveniently cast from a cycloaliphatic epoxy resin however it may be made from suitable known weather resistant thermoplastic or thermosetting resins by injection or compression moulding. For indoor applications where weather resistance is not an issue, any suitable polymeric composition having the properties required for such a housing may be employed. Such polymers may include silicone modified epoxy or polyester resins.

Alternatively body 6 may be cast, injection moulded, compression moulded or rotation moulded from a known curable polymeric compound such as a filled polyester resin.

The pre-moulding process provides a smooth locating cavity 5 of high dimensional tolerances.

In other variations the shape of the locating cavity 5 and the configuration of sleeve 2 may be adapted to a wide range of shapes and features.

FIG 2 shows an alternative embodiment in which the sleeve 2 of silicone rubber comprises a generally cylindrical central portion 2a and ribs 2b having frusto-conical outer surface generally complementary to that of inner wall 7. Like reference numerals are employed for like features.

FIG 3 shows still another embodiment in which a solid frusto-conical sleeve 2, of the same general configuration of the sleeve of FIG 1, has formed in its outer circumferential surface a plurality of spaced channels 13 which form a plurality of ribs 14 therebetween. Otherwise like reference numerals apply to like features.

In still further variations of the invention the interrupter sleeve may

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be formed by a castable or mouldable polymeric compound having suitable dielectric, thermal and mechanical properties. Such compounds may include polyurethanes, silicone rubbers, acrylic elastomers, butyl rubbers, vinyl resins, ethylene resins, polyesters, polyethers, epoxy resins or the like or mixtures or copolymers thereof without limiting the invention.

The sleeve may be formed by casting with a liquid curable compound or by insert injection or compression moulding.

In some applications, the sleeve 2 may be formed from a semi-conductive polymer or a combination of non-conductive and semi-conductive polymers.

FIGS 4-8 show further variations of the removable incorporation of a vacuum interrupter into an insulated housing. In these figures, where appropriate, like reference numerals are employed for like features.

FIG 4 shows a variations wherein sleeve 2 comprises a narrow rib located intermediate the ends of the ceramic wall of vacuum interrupter 1.

If required a channel-like recess 15 may be formed in the outer surface of rib 2 to form rib-like projections 16.

FIG 5 shows another embodiment wherein sleeve 2 is formed as a narrow rib adjacent the proximal end of interrupter 1.

In the case of the embodiments of FIGS 3 and 4, vacuum interrupter is firmly located in its recess 5 by tension on stud 9 and compressive engagement between the respective surfaces of sleeve 2 and wall 7.

FIG 6 shows a still further embodiment of the invention.

In this embodiment sleeve 2 and wall surface 7 are formed with complementary surfaces in the form of a coarse helical thread 17.

Sleeve 2 may be formed of hard or soft dielectric polymeric material and provides a substantially greater tracking path between the steel end caps of the vacuum interrupter.

To assist in locating the vacuum interrupter and in removal of air the threaded surface of sleeve 2 may be lubricated with a high dielectric lubricant such as silicone oil or silicon grease.

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The vacuum interrupter is driven home by a mechanical engagement with the fixed switch terminal socket or moulded lugs 18 formed on the proximal end of sleeve 2.

If removal of the vacuum interrupter for repairs or the like is not required, the lubricant may comprise a liquid curable adhesive composition.

If required, the helical thread surfaces on the sleeve 2 and the wall 7 may be formed as a tapered thread.

FIG 7 shows yet another embodiment of the invention.

In this embodiment, the vacuum interrupter is mechanically fastened into cavity 5 by means of stud 8 and nut 11 and thereafter a curable liquid polymeric material 19 is poured into the void between the ceramic surface of the interrupter.

The polymeric material may comprise an elastomer or it may comprise a more rigid material.

If removal of the interrupter is required, the inner wall 7 of housing 6 may be coated with a dielectric release agent such as silicone oil or silicone grease.

In still further variations of the invention the interrupter sleeve may be formed by a castable or mouldable polymeric compound having suitable dielectric, thermal and mechanical properties. Such compounds may include polyurethanes, silicone rubbers, acrylic elastomers, butyl rubbers, vinyl resins, ethylene resins, polyesters, polyethers, epoxy resins or the like or mixtures or copolymers thereof without limiting the invention.

The sleeve may be formed by casting with a liquid curable compound or by insert injection or compression moulding.

In some applications, the sleeve 2 may be formed from a semi-conductive polymer or a combination of non-conductive and semi-conductive polymers.

FIG 8 shows a modified form of the invention wherein the vacuum interrupter 1 comprises a conventional ceramic or glass bodied device having a polyurethane sleeve 2 fitted as part of the manufacturing

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process.

In the embodiment shown the sleeved interrupter 1 is located within body 6 with an air space in cavity 5 between the outer surface 2a of polyurethane sleeve 2 and the inner wall 7 and 6.

interrupter 1 is supported axially in the body 6 by tension from tubular nut 11 on the threaded stud 9 located in the threaded socket 10 of the fixed switch contact of interrupter 1.

FIG 9 shows another aspect of the invention wherein the underlying concepts of the aforementioned aspects of the invention are also embodied.

In FIG 9 there is illustrated a recloser housing 20 having one side of a high voltage conductor 21 coupled to a vacuum interrupter 22 (shown in phantom) as generally illustrated in FIGS 1-3.

The other side of conductor 21 is coupled to the movable switch contact 22a which is coupled via a push rod to a solenoid switch actuator (not shown) located below housing 20.

To facilitate easy assembly of the insulating housing 20 and its internal components (and otherwise to avoid complex mould structures and moulding techniques for encapsulation of internal componentry) the side arm housing 23 is formed as a separate moulding from the same material as main housing 20, for example, cycloaliphatic epoxy resin for good outdoor weathering properties.

Side arm housing 23 is formed with a socket-like aperture 24 to receive a spigot-like projection 25 formed integrally with main housing 20.

Spigot-like projection 25 has a central aperture in which is cast a conducting shaft 26 which is screw threadably engaged in a terminal 27 coupled to the movable switch contact of vacuum insulator 21.

Side arms housing 23 is secured to housing 20 by sliding it over the free end of shaft 26 until the mating socket and spigots engage. A resilient seal 28 is secured between shaft 26 and the inner wall of housing 23. Housing 20 and side arm housing 23 are secured under compression via a threaded nut 26a bearing on the outer end of side arm

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housing 23.

Hitherto, the electrical and mechanical integrity of the joint between the complementary frusto-conical faces 29, 30 of aperture 24 and projection 25 has relied upon an adhesive such curable liquid epoxy resin applied to faces 29, 30 during assembly.

A difficulty with this method is that while it is desirable to raise the temperature of the liquid epoxy resin adhesive to between 120°-160°C to achieve rapid and complete curing, the coefficient of thermal expansion of epoxy resins is not constant over the range of from say, ambient to 160°C.

In a glass transition temperature range rising from between about 100°-120°C, the coefficient of thermal expansion increases by nearly 100%.

A difficulty with this differential rate of thermal expansion is that initially, the liquid resin may exude from the joint as curing commences but after curing commences and during the cool down phase, stresses can occur at the interfaces of the newly cured resin bond and the previously cured components.

Apart from giving rise to the possibility of mechanical and electrical defects, this method of joining is permanent and does not lend itself to the prospect of easy in-field repairs.

Another difficulty associated with epoxy resin housings is that if the temperature of the housing exceeds the heat distortion temperature of the resin (about 105°C) the socket and spigot elements can distort to destroy the electrical and mechanical properties of the joint. In any event, in the glass transition temperature range the epoxy resin changes from a somewhat elastic medium to a plastic medium.

As shown in FIG 9, the present invention utilises the same concept for removable location of a vacuum interrupter in an insulating housing to removably locate a side arm housing with the same mechanical and electrical integrity.

Instead of employing a curable epoxy adhesive between the side

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arm housing 23 and the main housing 20, there is a compressed flexible polymeric sleeve 31 located therebetween.

Preferably the sleeve is comprised of an elastomeric silicone polymer as hereinbefore described. The sleeve 31 may be cast or moulded by any suitable process.

Suitably, the sleeve may include one or more locating ribs to locate in a corresponding circumferential channel 33 in frusto-conical face 29 and/or 30 or the inner and/or outer surfaces of the sleeve may simply include channelled recesses to allow for thermal expansion of the sleeve material into the recess cavities.

If required sleeve 31 can be cast directly onto spigot 25.

Conversely, the frusto-conical face 29 and/or 30 may include one or more circumferential ribs to locate in corresponding recesses (not shown) formed in the sleeve 31.

Preferably however, either or both of frusto-conical faces include one or more circumferential channels 33 which provide a space into which the material of sleeve 31 may expand during thermal cycling of the recloser assembly.

The one or more circumferential channels 33 suitably function as an air gap to increase the tracking path between conductors on opposite sides of the side arm joint to minimise partial discharge between the body and side arm joint and function in a manner similar to the embodiments of FIGS 2-5 previously described.

During assembly, sleeve 31 is placed over spigot-like projection 25, with or without a silicone oil lubricant and then pre-moulded side arm housing 23 is slid over sleeve 31 and threaded terminal shaft 26 is tensioned in threaded terminal 27 by means of flats or other suitable formations in the distal end 34 of conducting shaft 26.

Alternatively side arm housing 23 can be pre-heated to about 120°-160°C before assembly such that as the side arm housing 23 cools and contracts, it increases the degree of compression on sleeve 31 to form a tight weatherproof joint between side arm housing 23 and main

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housing 20.

If required, sleeve 31 may be applied to projection 25 in an expanded state (under vacuum or otherwise) and similarly the side arm housing 23 may be engaged over sleeve 31 under vacuum or otherwise to avoid any gas inclusions.

As shown schematically in FIG 5, a vacuum interrupter 40, having a coating of at least partially cured silane primer or other suitable adhesive on the ceramic surface 41 is inserted into a silicone sleeve 42 of the type shown in FIG 1, the sleeve being retained in a radially stretched state in a vacuum manifold 43 in a manner similar to that described in WO 98/11582 (PCT/US97/15936).

Vacuum manifold 43 is enclosed in a vacuum chamber 44 with conduits 45 attached to a vacuum pump to retain the sleeve in the stretched state while inserting the vacuum interrupter.

After the vacuum interrupter is inserted but before the vacuum in conduits 45 is released, chamber 44 is evacuated via conduit 46 also connected to a vacuum pump.

As the vacuum in chamber 44 reaches the same level of reduced atmospheric pressure (or slightly greater than) that in conduits 45, the sleeve 42 is released from the vacuum manifold by resilient recovery forces acting against the substantially equalised pressure on opposite sides of the sleeve.

Sleeve 42 then contracts about the vacuum interrupter in the substantial absence of gas molecules which might otherwise be occluded in a layer or pockets between the sleeve and the surface of the vacuum interrupter.

It is considered however that the use of a partially cured or fully cured silane primer on the sleeve contacting surfaces 29, 30 in most cases will be sufficient to avoid gaseous inclusions however in conjunction with a silicone oil lubricant on both surfaces this substantially will minimise the risk of gaseous inclusions.

It will be apparent to a skilled addressee that many modifications

and variations may be made to the invention without departing from the spirit and scope thereof.

For example in FIG 9, the main housing 20 may include a socket-like recess to receive a spigot-like projection on side arm housing 23.

Similarly where a transversely directed conductor is required at the top of main housing 20, the upper part of main housing 20 may be adapted to receive an insulated housing extension in a manner similar to side arm housing 23.

In another variation, sleeve 31 may be truncated by removal of the solid end portion 32 to form a generally cylindrical sleeve 31 which could be produced by extrusion as a parallel walled tube or by a moulding or casting process to form a frusto conical tube of constant wall thickness.

The parallel walled tubular sleeve is then stretched over spigot 25 whereby it is retained thereon by tension in the sleeve wall.

FIG 11 shows an alternative method for forming a modular housing assembly of the type generally shown in FIG 9 and in this figure, like numerals apply to like features.

After main housing 20 and side arm housing 23 are moulded from, say, cycloaliphatic epoxy resin, the respective mating frusto-conical surfaces 29, 30 of socket 24 and spigot 25 are machined to achieve finely finished surfaces with highly complementary tapers.

The complementarity can be enhanced by lapping the surfaces with a fine grit lapping compound. A 120 grit compound has been found to be satisfactory.

The preferred taper angle for socket 24 and spigot 25 is about 3° radially but depending upon the nature of the finish of the tapered surfaces, the angle of friction can vary. The maximum taper angle must be less than the angle of friction otherwise the components cannot be coupled by shrink fitting as described below.

The side arm 23 is heated to about 80°C or about 60°C above ambient to form a temperature differential between side arm 23 and main housing 20.

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The side arm 23 and housing 20 are then coupled together, nut 26a is tightened to the desired degree and the assembly is allowed to cool to ambient temperature.

By heat shrinking the side arm 23 on to main body 20 as described above, tension or hoop stress is induced in the socket wall while compression is induced in the spigot.

Under the temperature extremes of service conditions, relative expansion and contraction between the two elements is accommodated by the resilience of the epoxy resin materials.

At the upper end of the service temperature range, sufficient elasticity is retained to avoid separation of the components due to differential expansion.

Similarly at the lower end of the service temperature range, the stresses encountered by both the socket and spigot members are insufficient to permit fracture in the epoxy resin materials.

A particular advantage of the modular system described is that with straight insulated housing extensions similar to side arm housing 23 or an angled housing extension as described above is that insulated high voltage switch housings having a variety of adjustable configurations can be obtained. This avoids the need for a plurality of large body moulds where items such as the vacuum interrupter are required to be encapsulated in the body during the moulding process and also avoids the moulding difficulties associated with such large moulds.

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